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Authors	TERENZI, LUCA; CUTTAIA, FRANCESCO; VILLA, Fabrizio; BASILI, ANGELO; MARIOTTI, SERGIO; et al.
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iALMA Cryofacility Dry Run Report

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Prepared by		
Name	**Organization**	**Date**
Luca Terenzi Francesco Cuttaia Fabrizio Villa Angelo Basili Sergio Mariotti Giovanni Giusi	Uni E-campus INAF/IASF-Bologna INAF/IASF-Bologna INAF/IASF-Bologna INAF/ORA INAF/IAPS	10/10/2016
Approved by		
Name	**Organization**	**Date**
Fabrizio Villa	INAF/IASF-Bologna	18/10/2016

1 Change Record

Version	**Date**	**Affected sections**	**Reason**
0	18/10/2016	All	Draft version

2 Applicable and reference Documents

2.1 Applicable documents

AD-1.	B2+3 Warm Test Baseplate ICD	iALMA-TEC-ICD-IAB-001-H	2016
AD-2.	iALMA Cryofacility dry-run specifications	iALMA-TEC-SPE-IAB-001-A	2015
AD-3.	Cryostat Design Report	FEND-40.03.00.00-007-A-REP	2005
AD-4.			
AD-5.			

2.2 Reference documents

REF1.	ALMA Band 2(+3) Cryogenic Design Report	Report	2013
REF2.			
REF3.			
REF4.			

3 Table of content

4 Introduction and Scope

The iALMA Cryofacility consist of a 2x1 squared meters surface chamber that will permit to test the ALMA band 2+3 cartridge at operational conditions. The Cryofacility is setup at the CryoWaves Lab at INAF/IASF-Bologna.

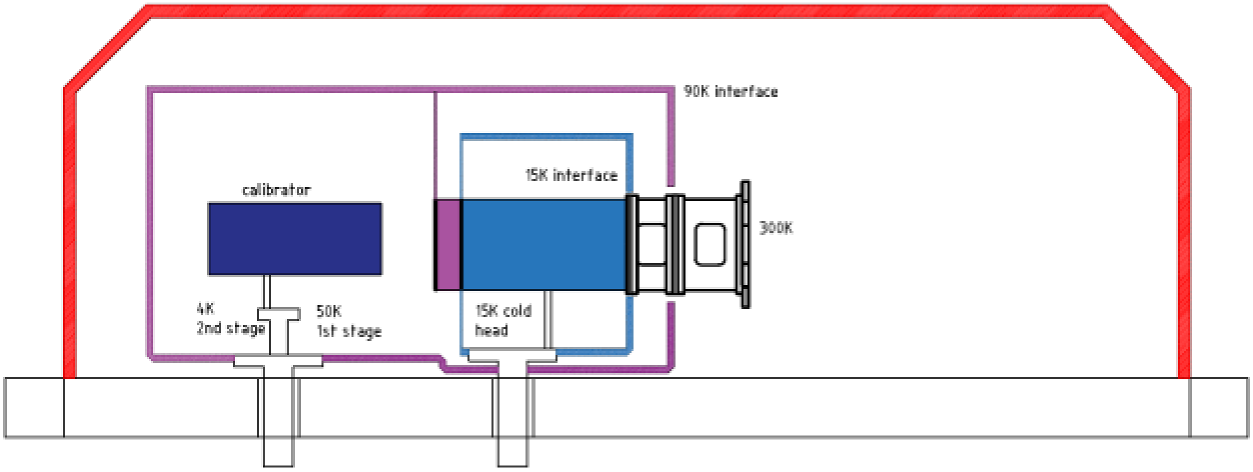

Figure 1: layout of the iALMA cryofacility @ IASFBO.

The Cryofacility is currently constituted by the following units:

- a Vacuum vessel
- Two 2-stage Cryocoolers
- Vacuum pumps (scroll plus turbo)
- Sensors and probes
- Electrical Ground Support Equipment

A detailed design of the main chamber temperature shields and supports at the different temperature stages has been developed taking into account the optimization of the interfaces with the prototype to be tested and additional dedicated devices used during the B2+3 cold tests.

Scope of this document is

(i) To describe the configuration of the Cryofacility dry run
(ii) To show the results of the facility dry run.

5 Dry Run Setup

The basic facility equipment to be used in the B2+3 cold tests consists of:

- a 2-stage 4K cooler by Sumitomo Heavy Industries, cold head model RDK415, capable to lift 1.5 W at the colder stage of 4.2 K and about 40 W at the 50K stage;
- a 2-stage 20K cooler by Leybold, cold head model COOLPOWER 5/100 capable to lift about 5 W at the colder stage of 20 K and about 100 W at the 100K stage;
- a scroll pump by Agilent Technologies, model TriScroll PTS300;
- a turbo-molecular pump by Agilent Technologies, model Turbo-V551 Navigator.

After several vacuum and leak detection tests a well repeatable vacuum level of less than 10^{-5} mBar is reached when the chamber is sealed and pumped down.

The two coolers have then been integrated in the facility and their cooldown performance has been measured through a set of dry runs.

The cold stage of each cooler is protected by a radiative shield as shown in the figure below of the whole chamber setup.

Figure 2 The dry run setup only consists of the two coolers in the chamber. Their cold stages are protected by radiative shields visible in the figure. The left (and higher) shield covers the 4K cooler while the shorter right shield surrounds the 20K cooler cold stage. The harness inside the chamber is used for reading temperature sensors, located in

the different stages of this setup. The white sheet at the center of the chamber base covers and protects the Turbo pump inlet when the chamber is open.

The temperatures of the main parts of this setup are monitored through silicon diode sensors, read through a single temperature monitoring instrument by LakeShore Cryotronics, model 218.

The list of sensors and locations are described in the table and figures below.

Id	**Sensor**	**Location**	**Id**	**Sensor**	**Location**
A	DT670 D60196	100K flange	E	DT670 D49530	Cold head 4K
B	DT670 D50519	Cold head 20K	F	DT670 D49018	50K flange
C	DT670 D49116	100K shield side	G	DT670 D50483	50K shield top
D	--	--	H	DT470 D49999	50K shield side

Table 1 The table reports the readout channel Id, the type and ID code of the sensors and the position inside the chamber.

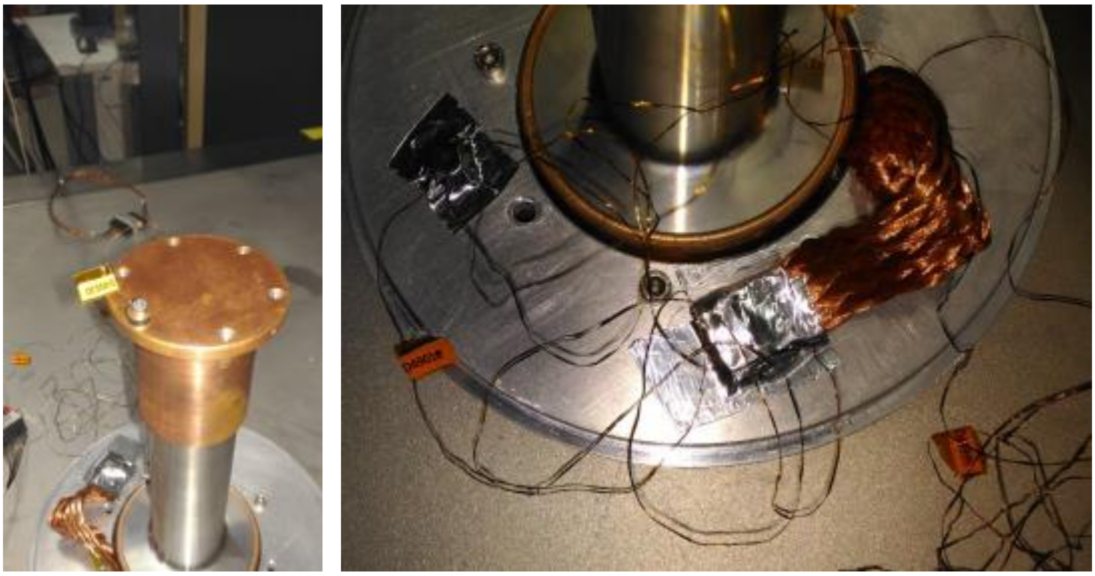

Figure 3 Left panel: location of the E sensor, screwed on the tip of 4K cooler cold end. Right panel: location of F sensor, by Al tape fixation, on the flange linked to the first stage of the 4 K cooler.

Figure 4 Locations of the G (left panel) and H (right) sensors on the top and the side of the shield covering 4K stage, respectively.

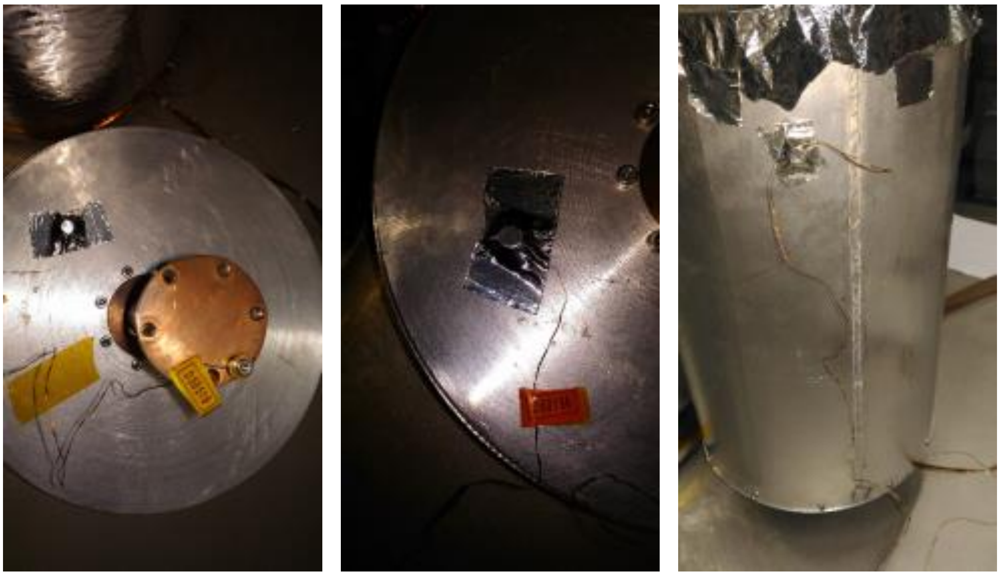

Figure 5 Left panel: location of the B sensor, screwed on the tip of 20K cooler cold end. Center panel shows A sensor mounted on the flange linked to the first stage of the 20 K cooler. Right panel: location of C sensor on the side of the shield covering the 20K stage.

6 First Dry Run data

After setting up the chamber as described in the previous section, it was closed and sealed in the afternoon of July, 12nd 2016, and pumped down all night long by the scroll pump until it reached a pressure less than 10^{-2}

mBar in the morning of July, 13rd 2016, when the turbo pump was activated. After the pressure dropped down below 10^{-4} mBar, on July, 13rd 2016 16:10 CET, the two coolers were activated and cooldown started.

As shown in the next figures, the colder stage of both the coolers quickly cooled down, in about two hours, close to their steady minimum temperatures, due to the low heat loads applied, in particular on the 20 K cooler. Second stage cold head of the 20K cooler got colder than 10 K after about one hour and reached after about a day of cooldown the minimum steady temperature oscillation, with about 0.5 K peak-to-peak amplitude, around about 7.5 K. The first stage flange reached in a couple of hours the minimum temperature of about 39 K, while the shield side reached 51 K, before drifting towards higher temperatures, due to a possible interaction with the adjacent shield on the 4K cooler.

Second stage cold head of 4K cooler got colder than 5 K after about one hour and reached after about a day of cooldown the minimum steady temperature of 3 K. Such a residual drift is probably due to the very high temperature of the shield covering it, which was not optimally linked to the first stage of the cooler. Due to space allocation inside the chamber the flange could not be joint directly on the cooler stage, so that the thermal contact between them was just due to a copper strap. So the shield flange and side surface reached steady temperatures of 93.2 and 103.5 K, respectively.

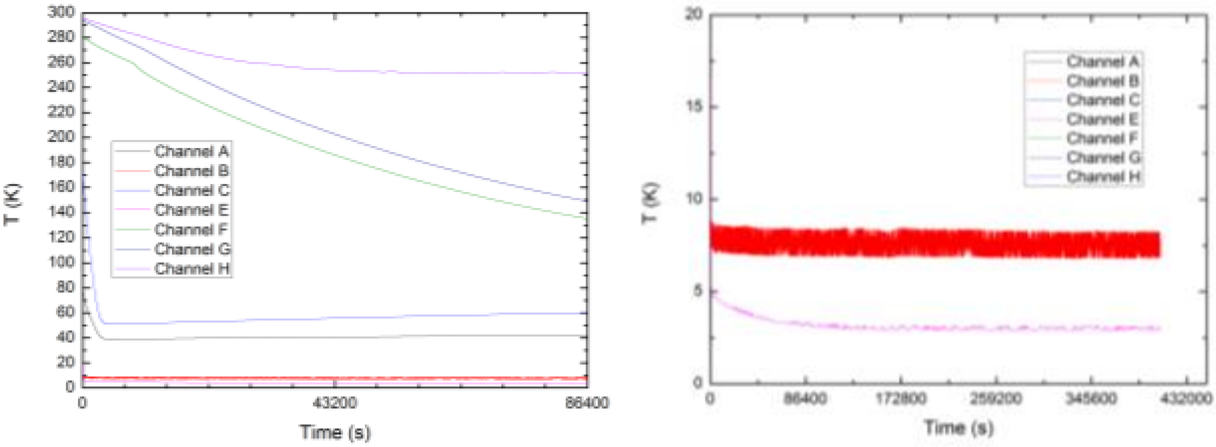

Figure 6 The overall behaviour of the different temperature stages during the first day of test, on the left, shows that the cold heads took a very short time to cool down. The detailed view of the two cold head during the whole 5 days run, on the right, highlights a residual slow drift witnessing that the steady lowest temperatures are reached actually at the end of the first day of cooldown.

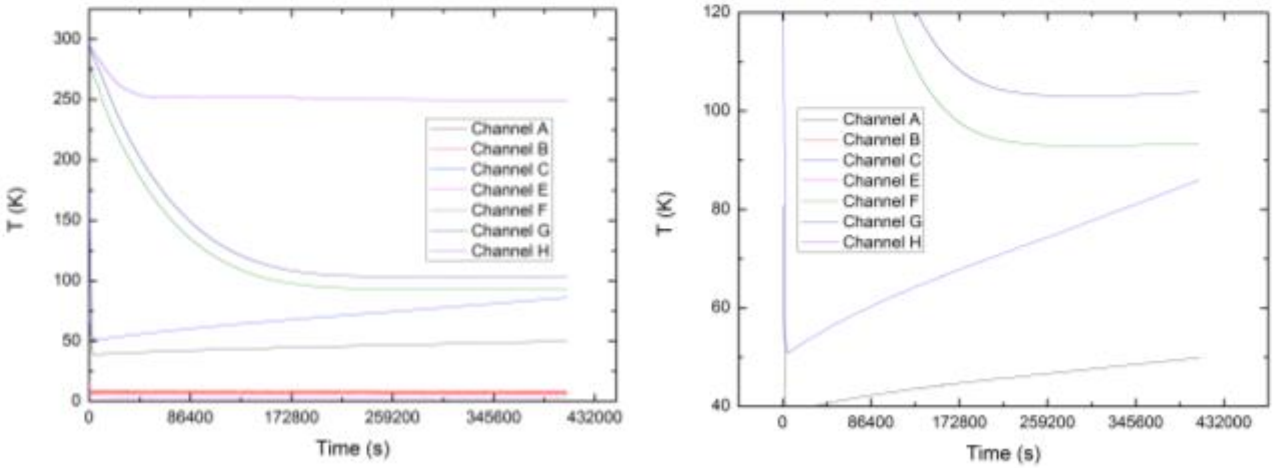

Figure 7 Left panel: the overall behaviour of the different temperature stages during the whole five days of test. The detailed view of the shield sensors temperature curves, on the right, evidences how the 20 K cooler shield drifts up towards the 4K cooler shield temperatures.

A new mechanical interface of the 4K cooler cold head to the chamber is being designed, in order to provide enough space for optimizing the contact of the first stage of the cooler to the corresponding shield, expected in the nominal tests.

On July, 18th 2016 at 10:20, coolers were switched off and the system warmed up to room temperature in about two days without any active heating.

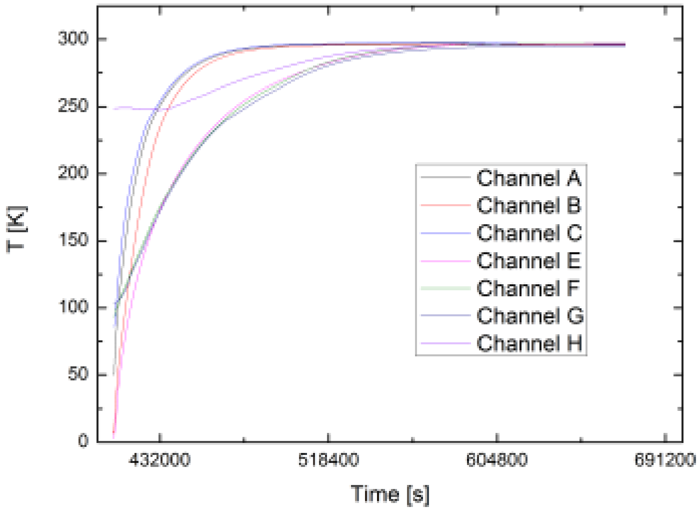

Figure 8 The whole system warmup temperature curves.

7 Target Panel Dry Run Setup

A second dry run has been performed in order to study the behaviour of a dummy cold load, submitted to a high environmental radiative load, like the shield covering the 4K stage, and cooled by the 4K cold head. The cold load is a panel of Eccosorb CR110 pyramids (10 mm base side x 30mm height) mounted on a supporting Aluminum base, 12.5 x 6.0 cm. It is then mounted on a 'L-shaped' black Aluminum support, screwed on the 4K cold head.

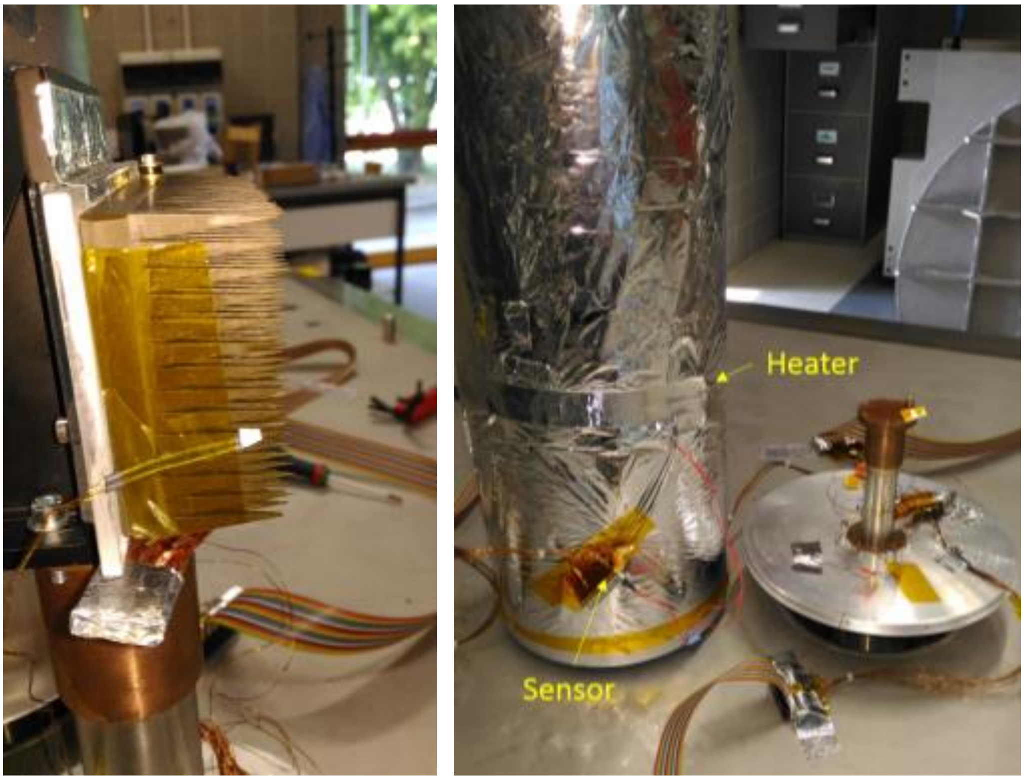

Figure 9 Left: the Eccosorb panel mounted on the black Aluminum support, which is screwed to the 4K cooler cold head. The small sensor mounted on one of the pyramids tip and the sensor mounted on the Eccosorb base of the target are also visible. Right the 4K stage is covered through an Aluminum cylinder, which has a ribbon heater on the side, together with a sensor to measure temperature variation of the radiative environment seen by the panel inside the shield.

The list of sensors and locations used in this second run are described in the table below.

Id	**Sensor**	**Location**	**Id**	**Sensor**	**Location**
A	DT670 D60196	100K flange	E	DT670 D49530	Cold head 4K
B	DT670 D50519	Cold head 20K	F	DT670 D49018	50K flange
C	DT670 D49116	100K shield side	G	DT670 D50483	Panel Base
D	DT470 D49999	50K shield side	H	DT670 D_SB	Pyramid tip

Table 2 The table reports the readout channel Id, the type and ID code of the sensors and the position inside the chamber.

The sensor and positions are the same as those in the first run, except the sensor on the top of the 50K shield, which is now located on the side of the Eccosorb base of the cold target panel; a small sensor has also been added and placed on the tip of one of the pyramids of the Panel. These last sensors are visible in Figure 9, on the right.

8 Target Panel Dry Run data

On July 21st, 18:34 CET, after the chamber was closed and sealed, the scroll pump was activated. The morning after, as the pressure reached a value of about 10^{-2} mBar, the turbo pump was activated. After the pressure dropped down below 10^{-4} mBar, on July, 22nd 2016 15:54 CET, the two coolers were activated and cooldown started. Unfortunately, due to a failure of the acquisition during the weekend, the temperature curves during the cooldown could not be recovered. So a short acquisition was run in order to record steady state cold temperatures. Values related to such a steady phase are reported in table below, and an overview of the temperature curves is given in the

Sensor Id - Location	**Mean T [K]**	**Standard Deviation [K]**
A - 100K flange	46.1	0.08
B - Cold head 20K	7.3	0.54
C - 100K shield side	67.6	0.22
D - 50K shield side	114.8	0.12
E - Cold head 4K	3.1	0.10
F - 50K flange	101.9	0.11
G - Panel Base	47.1	0.12
H - Pyramid tip	54.3	0.13

Table 3 Mean temperature and standard deviation measured during cold steady state

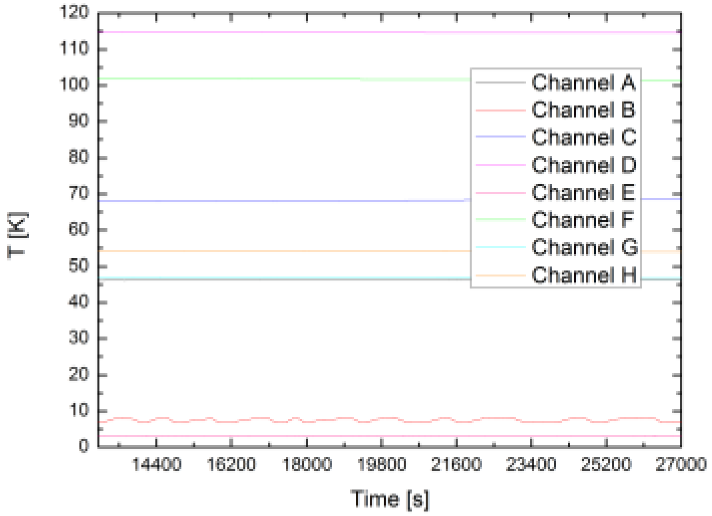

Figure 10 Temperature curve3s measured during steady state at low temperature.

It is worth noting that the temperatures of the first stage of the 20 K cooler are similar to those in the last part of the first dry run, i.e. after the shield side has drift towards the 4K cooler shield temperature. The 4K cooler first stage sensors have higher temperatures with respect to previous cooldown as well. With a radiative environment at about 100 K the gradient between the panel pyramid tip and base is about 7 K, while the poor conductance of the supports causes the Eccosorb base to be at 47 K.

A further phase of this second run is dedicated to the study of the temperature gradient within the target with respect to changes in the radiative environment temperature. By injecting power through the resistance heater ribbon mounted on the radiative shield surrounding the target panel, the temperature of the shield is increased and the larger radiative load on the pyramids let their temperature increase as well.

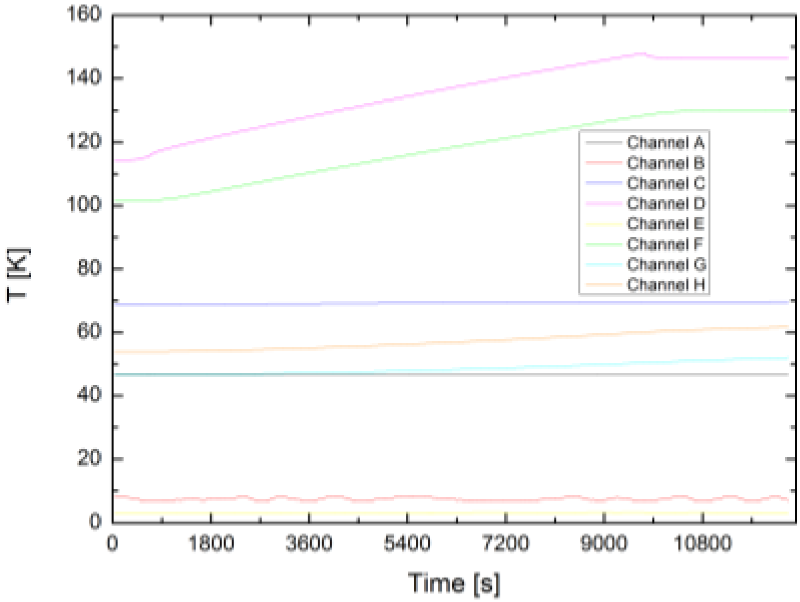

Figure 11 The overview of the shied heating phase of the test. It is evident how the stages affected by the heating are the shield side, where the heater is located, and base, together with the target pyramid and base, which are radiatively heated.

The shield heatup can be split in two phases:

- a first phase injecting 13.6 W on the shield causes its temperature drift at a rate of 3.4 mK/s, while the pyramid tip and the Eccosorb base are induced to drift as 0.75 mK/s and 0.53 mK/s, respectively;
- the second final phase, with the injection of 5.1 W, the system reaches an almost steady temperature setup.

In this final phase we measured that the impact of the radiative shield temperature increase, from 114.40 K to 146.25 K, on the temperature gradient between the pyramid tip of the target and Eccosorb base is an increase from 7.1 K to 9.7 K. The temperature difference between the panel base and the cooler cold end, which has a small increase of 0.1 K, due to larger heat load, varies from 43.4 K to 48.7 K.

On July 25th 2016 at 19:02 the coolers were switched off and the chamber warmed up to room temperature in less than 2 days.

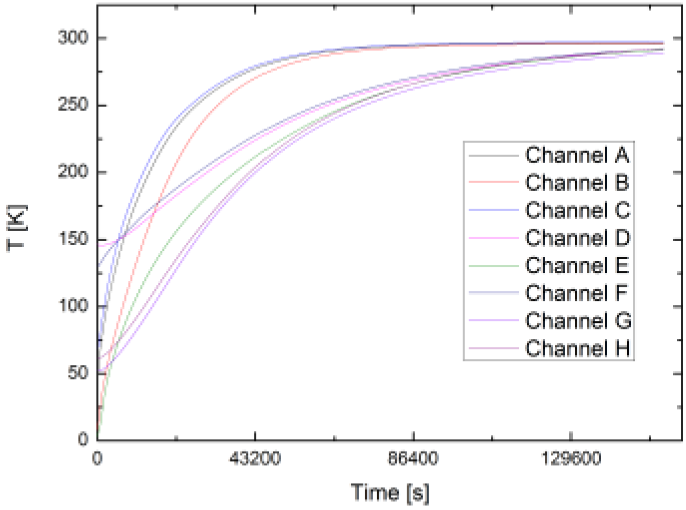

Figure 12 The chamber warmup temperature curves of the panel test run.

9 Summary and Conclusion

During the month of July 2016, two dry runs were performed for the iALMA cryo-facility located in its final site in the CryoWaves Lab at IASF Bologna. The chamber vacuum performance and the two cryocoolers functionality have been verified, together with the behaviour of a dummy cold load. The main thermal interfaces reached their nominal temperature, except the shield surrounding the 4K cooler cold head, whose mounting was not optimized due to mechanical constraints.

A change in the 4K cooler mounting interface with the chamber has been decided, in order to optimize the assembly of the corresponding radiative shield at 40 K. The new interface will be tested, together with nominal mechanical structure and shields currently under construction, in a final dry run of the complete cartridge test setup.